CALIFORNIA STATEWIDE
UTILITY CODES AND STANDARDS PROGRAM

2016 Title 24 Codes & Standards Enhancement (CASE) Proposal

Nonresidential Lighting – Partial-On Occupancy Sensors & Control Credits

CEC Staff Workshop, June 24, 2014

Michael Mutmansky, TRC

Proposed Code Change History

Title 24 is charged with being at least the equal in energy efficiency to the best national level codes.

- ASHRAE 90.1-2013 has established an approach for interior lighting controls that will result in lower lighting energy use by requiring many spaces to employ either a “Manual-ON” (Vacancy Sensor) or “Partial-ON” approach.
- ASHRAE 90.1 also establishes maximum occupancy sensor delay times, which varies based on the description of the space.

Proposed Code Change Overview

Nonresidential Lighting – Partial-On Occupancy Sensors

- Require some spaces to employ either “Partial-ON” or “Manual-ON” switching of the lighting.
- Require all installed lighting control systems employ a maximum sensor delay time of 20 minutes.
  - These apply to all building types and sensor applications.
  - These will be changes to Mandatory requirements.

Current Code Requirements

- The multi-level lighting requirement adopted in the 2013 Title 24 code revision applies to all areas >100 sf, with an LPD >0.5 W/sf and more than a single luminaire with two lamps.
- Shut-OFF controls are required in most spaces, but no direction is provided for when/how to turn ON the lights.
- Occupancy sensors ***specifically*** are required in offices 250 sf or less, multipurpose rooms less than 1000 sf, classrooms, and conference rooms.

Current Code Requirements

SAVINGS

- Compiled indirectly from a variety of sources, savings for this measure are estimated from 20% to 30% compared to a traditional Occupancy Sensor approach[1,2,3].
- The savings are impacted by the savings from Task Tuning, Daylight Savings, etc. but are considerable.

1. LBNL: Comparison of Control Options in Private Offices in an Advanced Lighting Controls Testbed. April, 2000.
2. LBNL: A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings. September, 2011.
3. CLTC: Bi-Level Switching in Office Spaces. February, 2010.

Typical Practices

Current practices

- While the use of lighting controls is widespread, many designers employ an Automatic-On (to 100% output) approach for spaces.
- Manual-On (Vacancy Sensors) is employed for energy efficiency projects and by “green” design teams regularly.

Typical Practices

Trends

- Lighting controls are not being viewed solely as a vehicle to turn off lights anymore; they are perceived as adding functionality and user customization capability to spaces.
- Lighting controls are becoming integrated; not just a single sensor connected to a branch circuit, but a sensor connected to an intelligence network.
- The new multi-level lighting requirement makes a Partial-On controls approach viable for many applications due to the inherent capability of a multi-level system to handle Partial-On levels.

Proposed Code Requirements

Proposed Title 24 Changes

- Add clarifying language to Section 110.9(b)3 that flicker requirement applies to entire dimming system (control, lamps and ballasts or drivers).
- Add language to Section 110.9(b)4 establishing a maximum sensor delay time of 20 minutes.
- Add language requiring either Manual-On or Partial-On in Section 130.1(c)5.
- Remove two Power Adjustment Factors in Table 140.6-A for Partial-On controls.
- Add two Power Adjustment Factors in Table 140.6-A for daylighting dimming plus OFF control and tuning of dimming systems

Proposed Code Requirements

Impacts to Section 130.1(c)5

- Require the employment of EITHER Partial-On or Manual-On approach. Applies only to
  - Office spaces less than 250 sf
  - Classrooms
  - Conference Rooms
  - Multipurpose rooms less than 1000 sf
- Add exception for:
  - Spaces that do not meet the threshold requirements for multi-level lighting (Section 130.1(b))

Proposed Code Change Language
Section 110.9(b)

3. **Dimmers** shall meet all requirements for Dimmer Control devices in the Title 20 Appliance Efficiency Regulations. The entire dimming system including lamps, ballasts or drivers if applicable and dimming control shall be designed so the combined performance of the dimming system results in amplitude modulation (percent flicker) of less than 30 percent for frequencies less than 200 Hz without causing premature lamp failure according to the Dimming Systems Flicker test method in Title 20.

4. **Occupant Sensing Controls:** Occupant, Motion, and Vacancy Sensor Controls shall meet the following requirements:

A. **Occupant Sensors** shall meet all applicable requirements for Occupant Sensor Control devices in the Title 20 Appliance Efficiency Regulations.

B**. Motion Sensors** shall meet all applicable requirements for Motion Sensor Controls devices in the Title 20 Appliance Efficiency Regulations.

C. **Vacancy Sensors** shall meet all applicable requirements for Vacancy Sensor Controls devices in the Title 20 Appliance Efficiency Regulations.

D. **Partial-ON Sensors** shall meet all applicable requirements for partial on sensing devices in the Title 20 Appliance Efficiency Regulations.

E. **Partial-OFF Sensors** shall meet all applicable requirements for partial off sensing devices in the Title 20 Appliance Efficiency Regulations.

F.All controls listed in Section 110.9(b)4 shall be programmed to turn off or reduce lighting power of controlled lighting equipment no longer than 20 minutes after the last occupant leaving the controlled zone, according to the applicable requirements of Section 130.1(c).

G.EXCEPTION to Section 110.9(b)4: Occupant Sensing Control systems may consist of a combination of single or multi-level Occupant, Motion, or Vacancy Sensor Controls, provided that components installed to comply with manual-on requirements shall not be capable of conversion by the user from manual-on to automatic-on functionality.

Proposed Code Change Language
Get rid of 1 out of 5 requirement in Section 130.1(b)3

(b) **Multi-Level Lighting Controls.** The general lighting of any enclosed area 100 square feet or larger, with a connected lighting load that exceeds 0.5 watts per square foot shall meet the following requirements:

1. Lighting shall have the required number of control steps and meet the uniformity requirements in accordance with TABLE 130.1-A; and

2. Multi-level lighting controls shall not override the functionally of other lighting controls required for compliance with Sections 130.1(a), and (c) through (e); and

3. Dimmable luminaires shall also be controlled by a manual dimmer according to Section 130.1(a)2C.

~~3. Each luminaire shall be controlled by at least of one of the following methods:~~

~~A. Manual dimming meeting the applicable requirements of Section 130.1(a)~~

~~B. Lumen maintenance as defined in Section 100.1~~

~~C. Tuning as defined in Section 100.1~~

~~D. Automatic daylighting controls in accordance with Section 130.1(d)~~

~~E. Demand responsive lighting controls in accordance with Section 130.1(e)~~

EXCEPTION 1 to Section 130.1(b): Classrooms, with a connected general lighting load of 0.7 watts per square feet and less, shall have at least one control step between 30-70 percent of full rated power.

EXCEPTION 2 to Section 130.1(b): An area enclosed by ceiling height partitions that has only one luminaire with no more than two lamps.

Pre-existing requirements in Section 130.1(a)2C (Area Controls): *C. If controlling dimmable luminaires, be a dimmer switch that allows manual ON and OFF functionality, and is capable of manually controlling lighting through all lighting control steps that are required in Section 130.1(b).*

Proposed Code Change Language
Section 130.1(c)5 Automatic Shut-off Controls

5. **Areas where Occupant Sensing Controls are required to shut OFF All Lighting.** In offices 250 square feet or smaller, multipurpose rooms of less than 1,000 square feet, classrooms of any size, and conference rooms of any size, lighting shall be controlled with occupant sensing controls to automatically shut OFF all lighting when the room is unoccupied. The occupant sensing controls shall function either as a:

   A. Partial-On Occupant Sensor, with the automatic ON level set between 50-70 percent of full rated power, OR

   B. Vacancy Sensor, where all lighting responds to a manual input only.

In addition, controls shall be provided that allow the lights to be manually shut-OFF in accordance with section 130.1(a) regardless of the sensor status.

EXCEPTION to Section 130.1(c)5: Areas that do not meet the multi-level requirements of Section 130.1(b) may operate using either Occupant Sensor or Vacancy Sensor control methods.

Proposed Code Change Language
Section 130.1(c) Automatic Shut-off Controls

Section 130.1(c)6

6. **Areas where partial ON/OFF occupant sensing controls are required** in addition to complying with Section 130.1(c)1.

   A. In aisle ways and open areas in warehouses, lighting shall be controlled with occupant sensing controls that automatically reduce lighting power by at least 50 percent when the areas are unoccupied. The occupant sensing controls shall independently control lighting in each aisle way, and shall not control lighting beyond the aisle way being controlled by the sensor.

Changes to…

6. Areas where partial ~~ON/~~OFF occupant sensing controls are required in addition to complying with…

Similarly, Section 130.1(c)7

7. **Areas where partial ON/OFF occupant sensing controls are required** instead of complying with Section 130.1(c)1.

   A. Lighting in stairwells and common area corridors that provide access to guestrooms and dwelling units

Changes to…

7. **Areas where partial ~~ON/~~OFF occupant sensing controls are required** instead of complying with…

Proposed: Remove Partial ON Osensor PAF Stricken Code Language from Section 140.6(a)2

§140.6(a)2. Reduction of wattage through controls. …

G. Lighting controls used to qualify for a PAF shall be designed and installed in addition to manual, multi-level, and automatic lighting controls required in Section 130.1, and in addition to any other lighting controls required by any provision of Part 6.

~~**EXCEPTION to Section 140.6(a)2G:** Lighting controls designed and installed for the sole purpose of compliance with Section 130.1(b)3 may be used to qualify for a PAF, provided the lighting controls are designed and installed in addition to all manual, and automatic lighting controls otherwise required in Section 130.1.~~

~~H. To qualify for the PAF for a Partial-ON Occupant Sensing Control in TABLE 140.6-A, a Partial-On Occupant Sensing Control shall meet all of the following requirements:~~

~~i. The control shall automatically deactivate all of the lighting power in the area within 30 minutes after the room has been vacated; and~~

~~ii. The first stage shall automatically activate between 30-70 percent of the lighting power in the area and may be a switching or dimming system; and~~

~~iii. The second stage shall require manual activation of the alternate set of lights, and this manual-ON requirements shall not be capable of conversion from manual-ON to automatic-ON functionality via manual switches or dip switches; and~~

~~iv. Switches shall be located in accordance with Section 130.1(a) and shall allow occupants to manually do all of the following regardless of the sensor status: activate the alternate set of lights in accordance with item (iii); activate 100 percent of the lighting power; and deactivate all of the lights.~~

~~L. To qualify for the PAF for Combined Manual Dimming plus Partial-ON Occupant Sensing Control in TABLE 140.6-A, (i) the lighting controls shall comply with the applicable requirements in Section 140.6(a)2J; and (ii) the lighting shall be controlled with a dimmer control that can be manually operated, or with a multi-scene programmable control that can be manually operated.~~

Reflects getting rid of 1 out of 5 requirement and Partial ON Osensor PAF

Clean-up Proposal to Section 130.1(d)2D Location for daylighting control adjustments

D. **Automatic Daylighting Control Installation and Operation**. For luminaires in daylight zones, automatic daylighting controls shall be installed and configured to operate according to all of the following requirements:

i. Photosensors shall be located so that they are not readily accessible to unauthorized personnel.~~, and the~~ The location where calibration adjustments are made to automatic daylighting controls shall ~~not~~ be readily accessible to ~~un~~authorized personnel but may be inside a locked case or under a cover which requires a tool for access.

Rationale:

- Intent of the requirement is to make it easier to re-calibrate controls – hard to do if calibration controls are 20 feet up in the air.
- Intent is to make readily accessible to authorized personnel
- …but limit control to unauthorized people via locked case, special tool access etc.

Proposed Added Code Language for Dimming Plus OFF Daylighting Control & Tuning PAF's

§140.6(a)2. Reduction of wattage through controls. …

H. To qualify for the PAF for daylight dimming plus off control, the daylight control and controlled luminaires must be capable of continuous dimming in response to daylight availability and to turn lights completely OFF when full daylight is available in the daylit zone. Only those luminaires in the primary sidelit daylit zone and the skylit daylit zone qualify for this PAF.

J. To qualify for the PAF for a Manual Dimming Controls with High Trim and Tuning ~~System~~ PAF-~~or a Multiscene Programmable Dimming System PAF~~ in TABLE 140.6-A, the lighting shall be controlled with a control that can be manually operated by the user and the control or the controlled lighting has a high end trim control. Design illuminance is listed on building plans and maximum lighting output is adjustable and is tuned within 10% of the design illuminance as verified by the acceptance test in the nonresidential standards appendix NA7.6.4 "Acceptance Tests for High End Trim Tuning of Dimmable Lighting".

Proposed Modifications to Table 140.6-A
LIGHTING POWER DENSITY ADJUSTMENT FACTORS (PAF)

TYPE OF CONTROL		TYPE OF AREA		FACTOR
a. To qualify for any of the Power Adjustment Factors in this table, the installation shall comply with the applicable requirements in Section 140.6(a)2 b. Only one PAF may be used for each qualifying luminaire unless combined below. c. Lighting controls that are required for compliance with Part 6 shall not be eligible for a PAF				
~~1. Partial-ON Occupant Sensing Control~~		~~Any area ≤ 250 square feet enclosed by floor-to-ceiling partitions;~~ ~~any size classroom, conference or waiting room.~~		~~0.20~~
1. Daylight Dimming plus OFF Control		Luminaires in skylit daylit zone or primary sidelit daylit zone		0.10
2. Occupant Sensing Controls in Large Open Plan Offices		In open plan offices > 250 square feet: One sensor controlling an area that is:	No larger than 125 square feet	0.40
			From 126 to 250 square feet	0.30
			From 251 to 500 square feet	0.20
~~3. Dimming System~~	~~Manual Dimming~~	~~Hotels/motels, restaurants, auditoriums, theaters~~		~~0.10~~
	~~Multiscene Programmable~~			~~0.20~~
3 Manual Dimming Controls with High End Trim and Tuning.		Luminaires in non-daylit areas in: offices, classrooms, library areas, hotel lobby and function areas, museums and transportation function areas.		0.05
4. Demand Responsive Control		All building types less than 10,000 square feet. Luminaires that qualify for other PAFs in this table may also qualify for this demand responsive control PAF		0.05
~~5. Combined Manual Dimming plus Partial-ON Occupant Sensing Control~~		~~Any area ≤ 250 square feet enclosed by floor-to-ceiling partitions;~~ ~~any size classroom, conference or waiting room~~		~~0.25~~

Proposed Acceptance Test for Tuning (1/2)

NA7.6.4 Acceptance Tests for High End Trim Tuning of Dimmable Lighting.

NA7.6.4.1 Construction Inspection

Prior to Functional testing, verify and document the following:

(a) All systems receiving the PAF credit for tuning have their design illuminance on the plans. Missing design illuminance values are obtained from building designer or building owner before proceeding with rest of test.

(b)The controlled lighting is not within any daylight zone.

(c) The manual dimming control or the controlled luminaires have high end trim control capability. The control or controlled luminaires able to be adjusted so that their maximum light output can be adjusted and that normal operation of the manual dimming control does not override the maximum light output.

(d) The wattage of controlled lighting on receiving the PAF credit for tuning matches the controlled lighting power.

Proposed Acceptance Test for Tuning (2/2)

NA7.6.4.2 Functional testing of High End Trim Tuning of Dimmable Lighting

For buildings with up to seven (7) enclosed areas claiming the Manual Dimming Controls with High End Trim and Tuning PAF, all areas shall be tested. For buildings with more than seven (7) areas claiming this PAF, sampling may be done on the seven largest enclosed areas with tuned dimming systems. If the any areas in the sample group of seven areas fails the acceptance test another group of seven areas must be tested. If any tested system fails it shall be tuned until it passes the test.

For each area to be tested do the following:

(a) Identify design footcandles for the spaces in the area from plans.

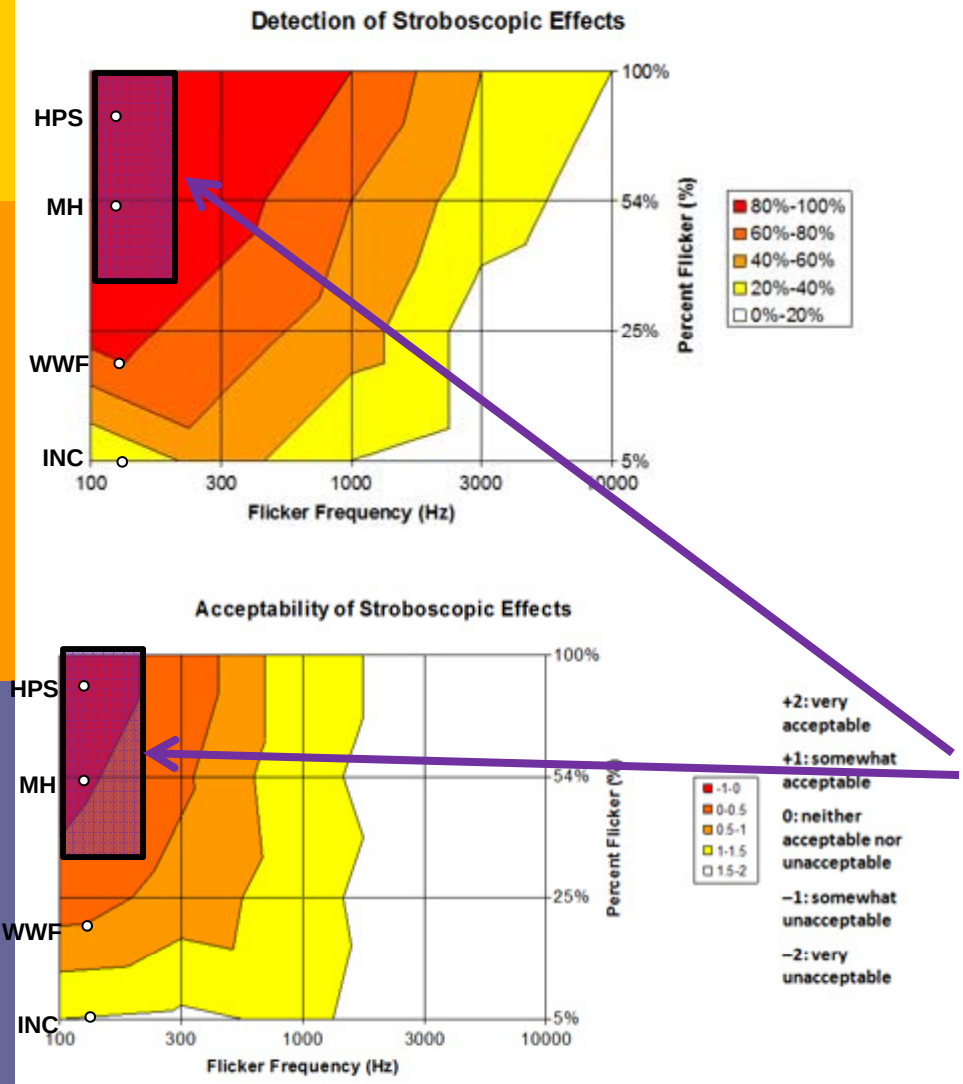
(b) Measure average illuminance due to controlled electric lighting at normal maximum output allowed (e.g. manual dimmer at full output, occupant controlled dimming sensing occupancy etc).

(c) Document that measured average illuminance due to controlled electric lighting does not exceed the design illuminance by more than 10%.

Rationale for Section 110.9 flicker requirement

- Flicker third most common reason for failure of daylighting controls after:
  - Daylighting control controlling too large of a space or luminaires that are in areas where daylight is not available (addressed by daylight area requirements)
  - Daylighting control not correctly commissioned (addressed by acceptance tests)
- Flicker also a reason for disliking high efficacy lighting

LRC 2011 Study on Flicker



- Detection and acceptability of flicker is a function of frequency and percent flicker (amplitude modulation)
- Red in top figure is most noticeable flicker
- Red in bottom figure is most unacceptable
- Rectangular boxes represents current T-20 definition of what is not *reduced flicker operation*.

http://www.lrc.rpi.edu/resources/newsroom/pdf/2011/Flicker8511.pdf

Preprint: IEEE Power Electronics Magazine, Vol. 1, No. 3, September 2014
Designing to Mitigate the Effects of Flicker in LED Lighting
By Brad Lehman, Arnold J. Wilkins

30% Modulation < 200 Hz

- Start with conservative metric for flicker
- Make use of definition refined for 2008 Title 24
- Test method proposed for Title 20 CA Appliance Stds

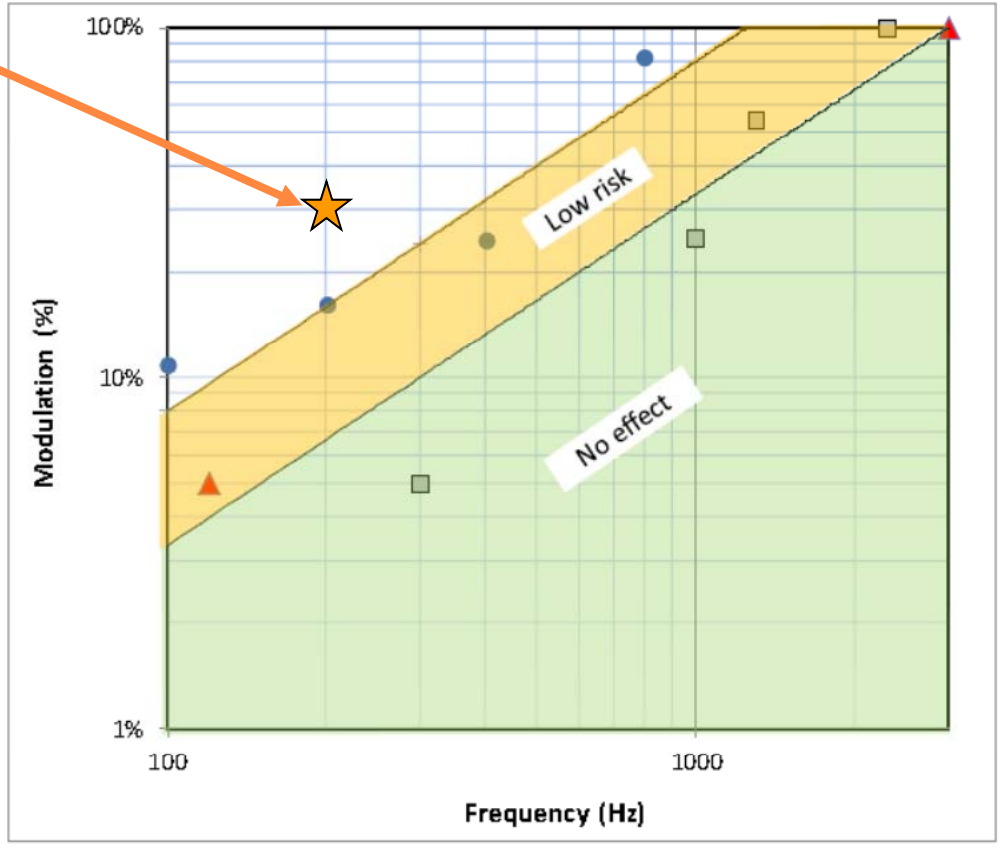


Fig.6 Low Risk (orange) and No Observable Effect (green) regions for flicker as a function of frequency and modulation percentage. The line Modulation(%) =0.0333 $f_{Flicker}$ separates the No Observable Effect and Low Risk regions, and the upper margin of the Low Risk region is given by the line Modulation(%) =0.08* $f_{Flicker}$.*

Proposed test method posted at: http://www.energy.ca.gov/appliances/2014-AAER-01/prerulemaking/comments/14-AAER-01_CA_IOUs_Response_to_Draft_Regulations_Dimming_Ballasts_Finalv2_2014-06-06_TN-73146.pdf

Rationale for 20 minute time delay for occupancy and vacancy controls

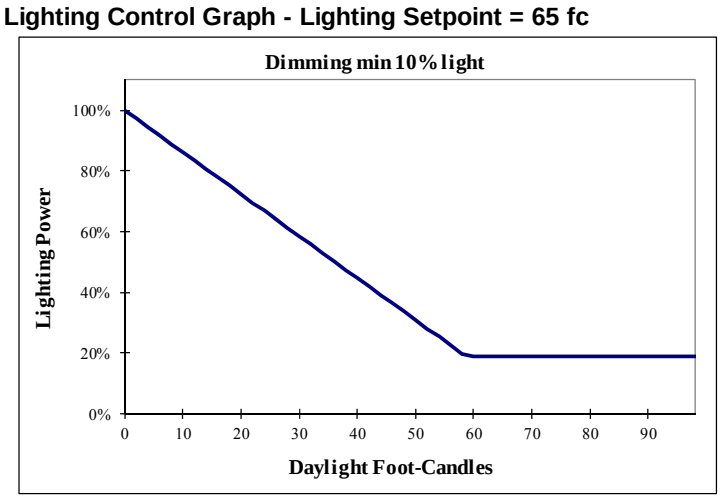
- T-20 CA Appliance Standard 1605(l)2(G) **Occupant sensing devices.** *1. All occupant sensing devices shall: a. be capable of automatically turning off controlled lights in the area* ***no more than 30 minutes*** *after the area has been vacated;*
- Title 24 proposal: Section 110.9(b)4F – "**programmed** … no longer than 20 minutes after the last occupant leaving the controlled zone."
- More savings from shorter time delay, but without requiring redesign of control. Control adjusted to 20 min delay time.
- Harmonization with 2013 ASHRAE 90.1 Interior Lighting Controls.
  - §9.4.1.1(g) *Automatic partial OFF (full OFF complies):* The general lighting power in the space shall be automatically reduced by at least 50% within 20 minutes of all occupants leaving the space
  - *§9.4.1.1(h) Automatic full OFF*: All lighting shall be automatically shut off within 20 minutes of all occupants leaving the space. A control device meeting this requirement shall control no more than 5000 ft2.

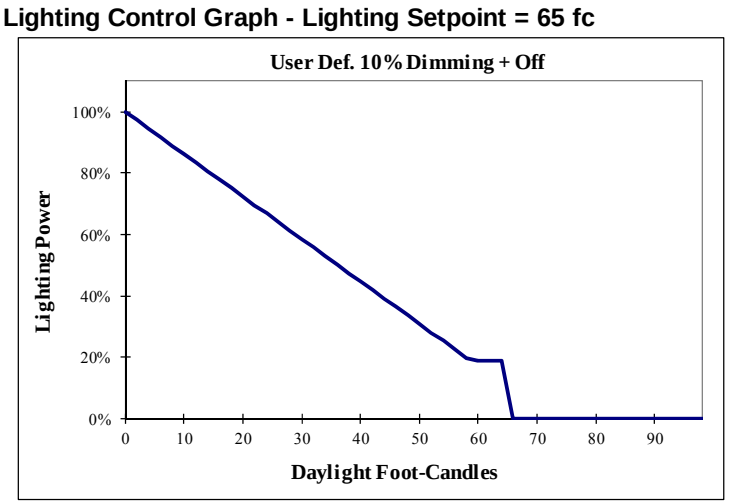
Proposed Code Requirements Section 130.1(c) Rename Partial ON/OFF to Partial OFF.

- Distinguish between Partial-On and Partial-Off control approaches so that Partial-Off is viably employed in those spaces where currently required, (Sections 130.1(c) 6 & 7). Designate these sections as ‘Partial-Off’ controls.

Rationale for dimming plus OFF Control PAF §140.6

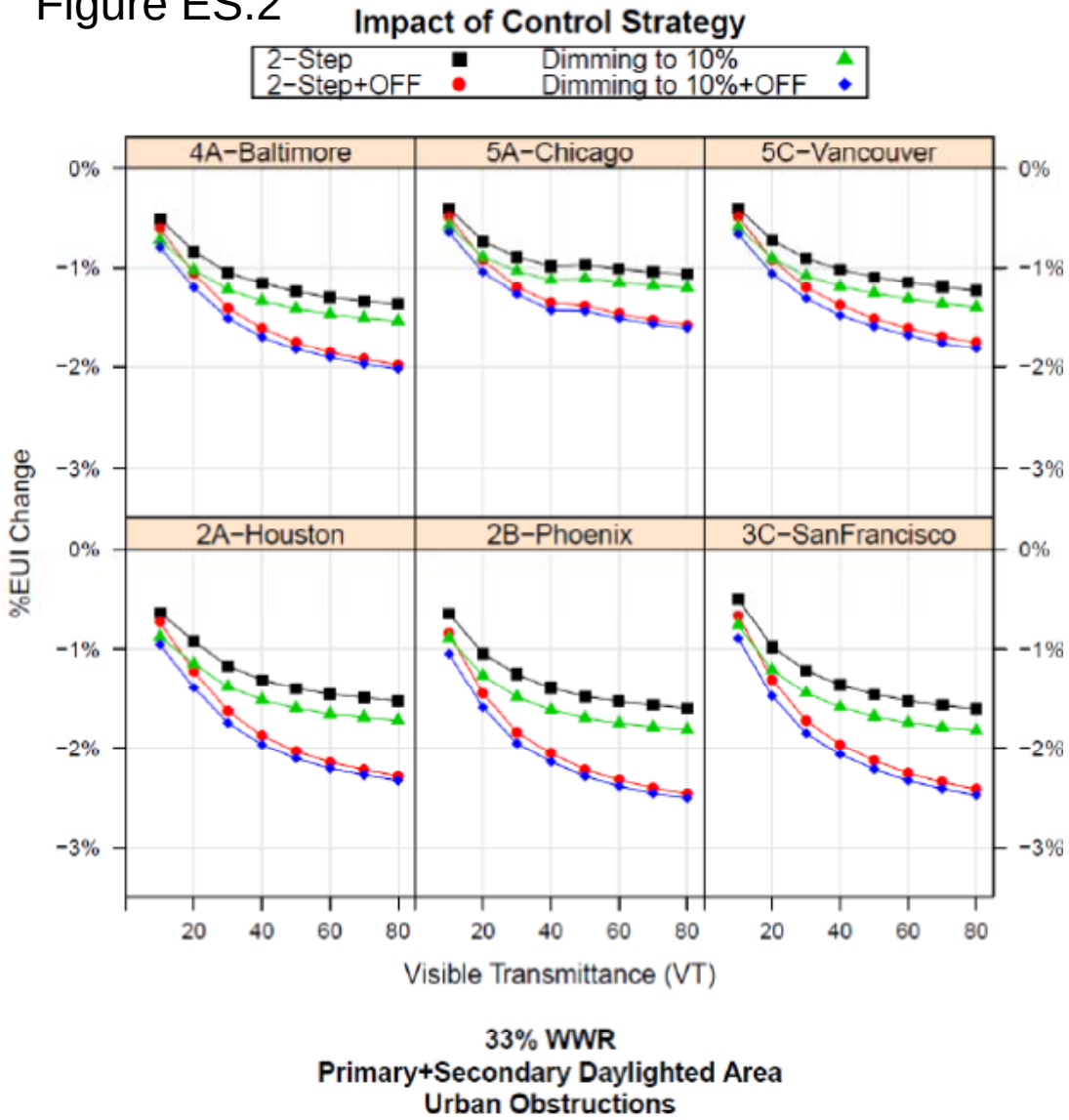
- Saves lots of energy.
  - 10%+ savings using SkyCalc skylighting software
- ASHRAE 90.1 §9.4.1.1(e):
  - *The photocontrol shall reduce electric lighting in response to available daylight using continuous dimming or with at least one control point between 50% and 70% of design lighting power, a second control point between 20% and 40% of design lighting power or the lowest dimming level the technology allows, and a third control point that turns off all the controlled lighting.*





PNNL Energy Research in Support of ASHRAE 90.1
Impact of Lighting Control Strategy at Different VTs

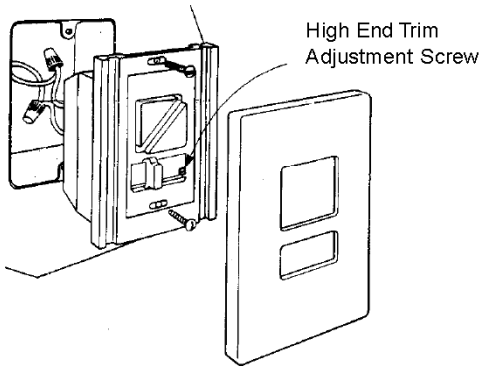
Figure ES.2

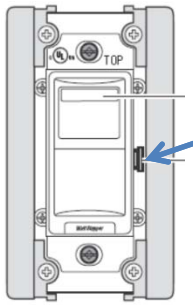


- Analysis of Daylighting Requirements within ASHRAE Standard 90.1
  - Report No. PNNL-22698
- **Important to turn lights all the way off at daylight saturation**
- High VT more daylight saturation
- Energy impacts more affected by turning luminaires all the way off, than by dimming versus stepped control.

Tuning Power Adjustment Factor (PAF)

- Integer quantities of luminaires
- Spacing is limited by uniformity and ceiling grid
- Often an excess amount of light provided by the lighting system.
- Tuning may save as much as 15% of the energy consumed by a lighting system.
  - Requirements for Controllable Lighting.. 2011 California Building Energy Efficiency Standards Final Draft Report March 21, 2011. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-04-04_workshop/review/Nonres_Controllable_Lighting.pdf
- Designer places design footcandles on plans for spaces seeking trim PAF
- Requires tuning luminaire high end trim or central high end trim on control or at ECMS system.
- Tuning verified by acceptance test.





Appendix: Input from Stakeholders

Input from Stakeholders

- [Comment] The incremental savings from additional controls is not that great. The LBNL meta-study shows this effect.
  - [CASE Team] We do not agree with this conclusion. The results of many of the studies that were included in the meta-study were of limited scope, and the attribution of each of the savings will be affected by the loading order unless the field study is very carefully performed. Most of those studies included in the meta-study were not attempting to achieve this. In fact, very high savings percentages have been recently observed as part of more recent studies, clearly in the realm of worthwhile to achieve.

Input from Stakeholders

- [Comment] I am concerned about lights coming on in the dimmed state, can cause flicker and strobe problems.
  - [CASE Team] This is an issue, but in many cases this is a result of improperly paired ballasts and lamps, not necessarily the fault of the dim level, especially since the level that the lighting is required to energize at is in the 50-70% range, rather than at a very low level. This concern will be considered in the language proposed for the code revision.

Input from Stakeholders

- [Comment] Why only spaces with occupancy sensors? Wouldn't manual-ON be considered for all (or many) spaces in addition to those with mandated occupancy sensors?
  - [CASE Team] This is valid, but in fact, manual-ON is a viable controls approach for most spaces, even if they have no requirement for occupant controls, but is not required. Requiring manual-ON for many spaces is difficult because of 'ownership' issues with the space (who can rightly control the lights in a multiple-occupant space). Many spaces also are not viable because of the transience of the occupants, who may not know to operate a switch to turn the lights ON. As a result, it is up to the designer to apply this approach, but probably should not be mandatory.

Input from Stakeholders

- [Comment] Changing Section 110.9 is a change to the requirement of the lighting product.
  - [CASE Team] This is not correct. Title 20 deals with the controls devices as an appliance. In 110.9, it refers to Title 20 for these items, and indicates that the devices must meet the requirements of Title 20. In the past, this was part of Section 110.9, but that moved to Title 20 in a previous revision cycle.
- On the 20 minute program time, say it is ‘no more than 20 minutes’.
  - [CASE Team] Agreed.

Input from Stakeholders

- [Comment] Dimmed lamps are especially problematic with 28 and 25 watt T8 lamps.
  - [CASE Team] These are indeed a problem, but the application of 28 and 25 watt lamps are an energy savings measure that works in some applications, but introduces many of these compatibility problems as well.
  - [CEC, Benya] There is almost no reason to be using the low output lamps now, when low output ballasts are available, plus task tuning.
  - [CASE Team] Further, the fixture wattage (for code compliance) is connected to the ballast, not the lamp, so if a normal output ballast is being used, you must calculate the wattage using the normal output lamps (F32T8), as opposed to the low output lamps, so there is no benefit to using this approach for compliance purposes.

Input from Stakeholders

- [Comment] Is the intent to permit either manual-ON or partial-ON in the spaces where this requirement applies?
  - [CASE Team] Yes. The decision is up to the designer to make.
- [Comment] If we are doing Modifications-in-place and below the 85% LPD threshold, will partial-ON be required, or exempt?
  - [CASE Team] Required. The partial-ON or manual-ON control approach is required because Section 130.1(b) and Section 130.1(c) are triggered regardless of the LPD installed. Note that bi-level switching is permitted in this 'below 85%' realm, which does still satisfy the partial-ON requirements, by being within the 50-70% for the first step.

Input from Stakeholders

- [CEC, Benya] Might a PAF infrastructure be viable to encourage devices with very short delay times to be specified?
  - [CASE Team] This is a good suggestion, but there are no products currently on the market. We must investigate the viability and interest in this as a market priming device.

Questions?

Michael Mutmansky
mmutmansky@trcsolutions.com